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Enhanced Medical Image Fusion Using Adaptive NSCT

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Abstract—Multimodal medical image fusion, as a powerful tool for the clinical applications, has developed with the advent of various imaging modalities in medical imaging. The main motivation is to capture most relevant information from sources into a single output, which plays an important role in medical diagnosis. In this paper, a novel fusion framework is proposed for multimodal medical images based on non-sub sampled contour let transform (NSCT). The source medical images are first transformed by NSCT followed by combining low- and high-frequency components. Two different fusion rules based on phase congruency and directive contrast are proposed and used to fuse low and high frequency coefficients. Finally, the fused image is constructed by the inverse NSCT with all composite coefficients.

Keywords: *Multimodal medical image fusion, non-sub sampled contour transform, phase congruency, directive contrast.*

I. INTRODUCTION

In the recent years, medical imaging has attracted increasing attention due to its critical role in health care. However, different types of imaging techniques such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), etc., provide limited information where some information is common, and some are unique. For example, X-ray and computed tomography (CT) can pro- vide dense structures like bones and implants with less distortion, but it cannot detect physiological changes [1]. Similarly, normal and pathological soft tissue can be better visualized by MRI image whereas PET can be used to provide better information on blood flow and flood activity with low spatial resolution. As a result, the anatomical and functional medical images are needed to be combined for a compendious view.

The salient contributions of the proposed framework over existing methods can be summarized as follows.

• This paper proposes a new image fusion framework for multimodal medical images, which relies on the NSCT domain.
• Two different fusion rules are proposed for combining low and high-frequency coefficients.
• For fusing the low-frequency coefficients, the phase congruency based model is used. The main benefit of phase congruency is that it selects and combines contrast- and brightness-invariant representation contained in the low-frequency coefficients.
• On the contrary, a new definition of directive contrast in NSCT domain is proposed and used to combine high frequency coefficients. Using directive contrast, the most prominent texture and edge information are selected from high-frequency coefficients and combined in the fused ones.
• The definition of directive contrast is consolidated by incorporating a visual constant to the SML based definition of directive contrast which provide a richer representation of the contrast.
• Further, the proposed scheme is also extended for multi-spectral fusion in color space which essentially rectifies the HIS color space undesirable cross-channel artifacts and produce best quality output with natural spectral features and improved the color information.

A. *NON-SUB SAMPLED CONTOUR LET TRANSFORM (NSCT)*

NSCT, based on the theory of CT, is a kind of multi-scale and multi-direction computation framework of the discrete images. It can be divided into two stages including non-sub sampled pyramid (NSP) and non-sub sampled directional filter bank (NSDFB). The former stage ensures the multi scale property by using two-channel on-sub sampled filter bank, and one low frequency image and one high-frequency image can be produced at each NSP decomposition level. The subsequent NSP decomposition stages are carried out to decompose the low-frequency component available iteratively to capture the singularities in the image. As a result, NSP can result in sub-images, which consists of one low-and high-frequency image shaving the same size as the source image where denotes the number of decomposition levels. Fig. 1 gives the NSP decomposition with levels.

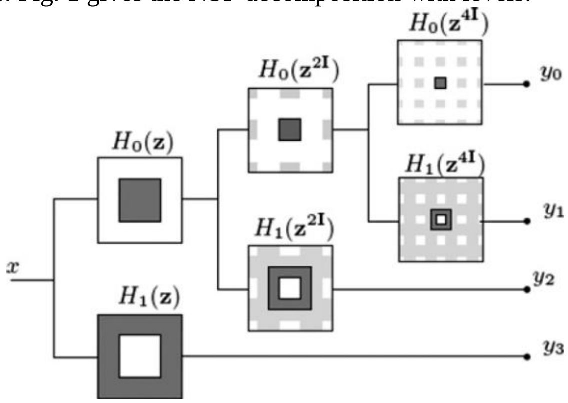

Fig. 1. Three-stage non-sub sampled pyramid decomposition

The NSDFB is two-channel non-sub sampled filter banks which are constructed by combining the directional fan filter banks. NSDFB allows the direction decomposition with stages in high-frequency images from NSP at each scale and produces directional sub-images with the same size as the source image. Therefore, the NSDFB offers the NSCT with the multi-direction property and provides us with more precise directional details information.

B. *PHASE CONGRUENCY*

Phase congruency is a measure of feature perception in the images which provides an illumination and contrast invariant feature extraction method. This approach is based on the Local Energy Model, which postulates that significant features can be found at points in an image where the Fourier components are maximally in phase. Furthermore, the angle at which phase congruency occurs signifies the feature type. The phase congruency approach to feature perception has been used for feature detection.

The main properties, which acted as the motivation to use phase congruency for multimodal fusion, are as follows.

• The phase congruency is invariant to different pixel intensity mappings. The images captured with different modalities have significantly different pixel mappings, even if the object is same. Therefore, a feature that is free from pixel mapping must be preferred.

• The phase congruency feature is invariant to illumination and contrast changes. The capturing environment of different modalities varies and resulted in the change of illumination and contrast. Therefore, multimodal fusion can be benefitted by an illumination and contrast invariant feature.

• The edges and corners in the images are identified by collecting frequency components of the image that are in phase. As we know, phase congruency gives the Fourier components that are maximally in phase. Therefore, phase congruency provides the improved localization of the image features, which lead to efficient fusion.

II. PROPOSED IMAGE FUSION FRAMEWORK

In this section, we have discussed some of the motivating factors in the design of our approach to multimodal medical image fusion. The proposed framework realizes on the directive contrast and phase congruency in NSCT domain, which takes a pair of source image denoted by and to generate a composite image. The basic condition in the proposed framework is that all the source images must be registered in order to align the corresponding pixels.

A. DIRECTIVE CONTRAST IN NSCT DOMAIN

The contrast feature measures the difference of the intensity value at some pixel from the neighbouring pixels. The human visual system is highly sensitive to the intensity contrast rather than the intensity value itself. Generally, the same intensity value looks like a different intensity value depending on intensity values of neighbouring pixels which is defined above.

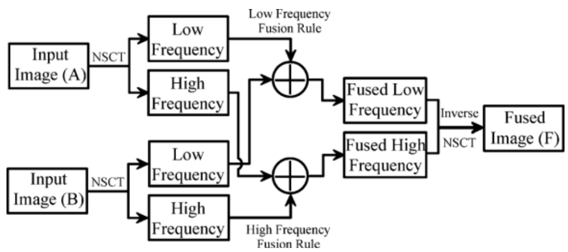

Fig. 2. Block diagram of proposed multimodal medical image fusion Frame work

In general, the larger absolute values of high-frequency coefficients correspond to the sharper brightness in the image and lead to the salient features such as edges, lines, region boundaries, and so on. However, these are very sensitive to the noise and therefore, the noise will be taken as the useful information and misinterpret the actual information in the fused images. Hence, a proper way to select high frequency coefficients is necessary to ensure better information Interpretation. Hence, the sum modified Laplacian is integrated with the directive contrast in NSCT domain to produce accurate salient features.

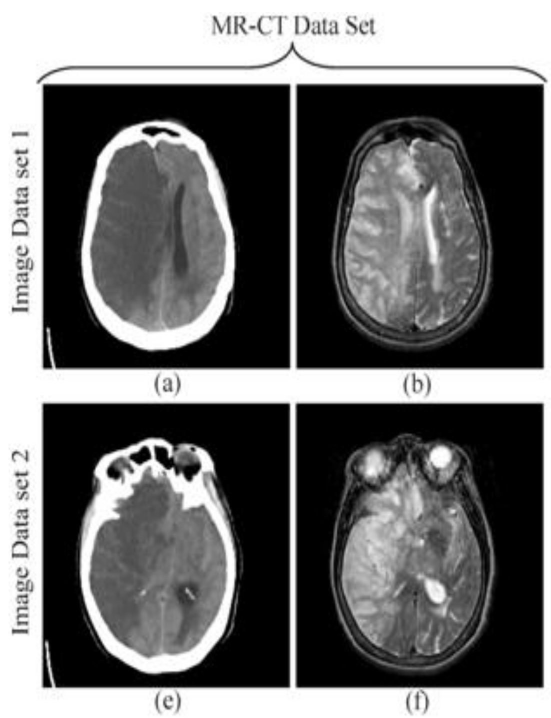

Fig. 3. Multimodal medical image data sets

III. PROPOSED FUSION FRAME WORK

In this subsection, the proposed fusion framework will be discussed in detail. Considering, two perfectly registered source images and the proposed image fusion approach consists of the following steps

1. Perform -level NSCT on the source images to obtain one low-frequency and a series of high-frequency sub-images at each level and each level and direction, where are the low-frequency sub-images and represents the high-frequency sub-images at level in the orientation.

2. Fusion of Low-frequency Sub-images: The coefficients in the low-frequency sub-image represent the approximation component of the source images. The simplest way is to use the conventional averaging methods to produce the composite bands. However, it cannot give the fused low-frequency component of high quality for medical image because it leads to the reduced contrast in the fused images. Therefore, a new criterion is proposed here based on the phase congruency. The complete process is described as follows. First, the features are extracted from low-frequency sub-images using the phase congruency.

3. Fusion of High-frequency Sub-images: The coefficients in the high-frequency sub-images usually include details component of the source image. It is noteworthy that the noise is also related to high-frequencies and may cause miscalculation of sharpness value and therefore affect the fusion performance. Therefore, a new criterion is proposed here based on directive contrast. The whole process is described as follows. First, the directive contrast for NSCT high-frequency sub-images at each scale and orientation, denoted by and at each level in the direction. Algorithms and the proposed frame- work.

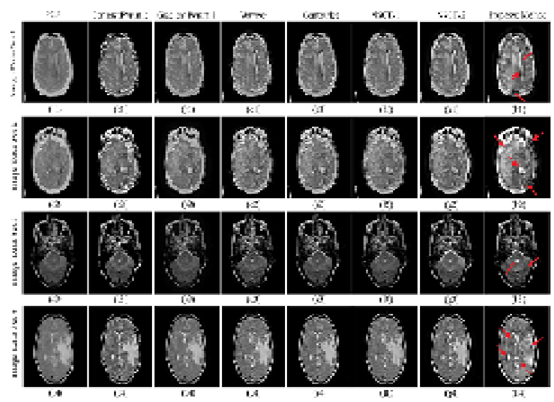

Fig. 4. Multimodal medical image fusion results

It can be seen that due to various imaging principle and environment, the source images with different modality contain complementary information. For all these image groups, results of proposed fusion frame work are compared with the traditional PCA (MS rule), Contrast Pyramid, Gradient Pyramid, wavelet, contour let and non-sub sampled contour let (NSCT-1andNSCT-2) based methods.

In order to do affair comparison, the same experimental images are used for all existing methods. The level of decomposition is set to 3 for all the pyramid, wavelet and contour let based methods, including proposed. For wavelet based method, images are decomposed using the ‘db4’ wavelet since it has used frequently in the existing wavelet based methods. For implementing NSCT, maximally flat filters and diamond maxflat filters are used as pyramidal and directional filters respectively.

IV. CONCLUSION

In this paper, a novel image fusion framework is proposed for a multi-modal medical image, which is based on non-sub- sampled contour let transform and directive contrast. For fusion, two different rules are used by which more information can be preserved in the fused image with improved quality. The low- frequency bands are fused by considering phase congruency whereas directive contrast is adopted as the fusion measurement for high-frequency bands. In our experiment, two groups of CT/MRI and two groups of MR-T1/MR- T2 images are fused using conventional fusion the proposed algorithm can enhance the details of the fused image, and can improve the visual effect with much less information distortion than its competitors. These statistical assessment findings agree with the visual assessment. Further, in order to show the practical applicability of the proposed method, three clinical examples are also considered which includes analysis of diseased person's brain with Alzheimer, sub acute stroke and recurrent tumor.

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